BROADBAND ACCESS TECHNOLOGIES: EVALUATION TOOL

João Paulo Ribeiro Pereira[1], José Adriano Pires [2]

Abstract *— Broadband technologies have view great growth over the past decade. But, the main part of this development and growth has been in the core networks, and the capacity of the access network to delivery broadband services remains as a challenge ("last mile problem"). The access network remains a bottleneck in terms of the bandwidth and service quality it affords the end user. By other side, the access network is much more spread geographically and covers larger areas. Then, this part of the network is usually the most expensive component in terms of capital investment and OAM cost. Some studies reefer that this networks required 70% of the total investment. Several access technologies can be used in this part of the network, which can be used to resolve the bandwidth bottleneck and the investment problem: xDSL, HFC, FTTx, FWA, WiMAX, PLC, Satellite, etc.*

This paper presents a methodology and a tool that compare and evaluate broadband access technologies. The paper presents a techno-economic analysis of eight broadband technologies for access networks: digital subscriber line (DSL), hybrid fiber coax (HFC), power line communications (PLC), fiber to the home (FTTH), fiber to the curb (FTTC), fiber to the cabinet (FTTCab), and wireless alternatives such as WiMAX and satellite. Several actors (such operators, service providers, …) could use this tool to compare different technological solutions, forecast deployment costs, compare different scenarios, etc.

Index Terms — Access networks, Broadband access technologies, Cost model.

INTRODUCTION

Full broadband coverage is highly important for bridging the digital divide. The digital divide expresses the difference in ability for people to communicate and utilize e-based business and services relative to their geographical location, their living standards and their level of education [1]. It is viewed ultimately as an indicator of a country's economic and social situation. Access to ICT as a development tool for society is recognized as a political, economic and social issue of high importance. One of the factors mitigating this digital divide is broadband access, not only in urban areas, but also in rural and developing areas. However, the residential access network infrastructure remains one of the major obstacles to the deployment of a broadband telecommunications network.

An access network infrastructure must be established for delivery of a complex mix of broadband services like fast Internet access, telecommuting, and video on demand in a market of great demographic diversity [2]. Actually, residential broadband access is mainly used for high-speed Internet and telephony services. The requirements for higher access capacities are primarily driven by the increase use of several broadband user terminals in the home and introduction of live TV streaming.

Until few years ago, Internet access for residential users was almost exclusively made via the public switched telephone networks (PSTN) over the twisted copper pair [3]. The new services requirements demand high-speed broadband access, and led to the development of several last-mile solutions (xDSL, HFC, FTTx, PLC, FWA, Satellite…) capable to support the services that internet has to offer.

The digital society increased the rapid bandwidth demand that put pressure on the network. Although national networks are largely upgraded to cope with this demand, a bottleneck remains over the 'last (or first) mile' between the customer and the first node in the network.

The methodology and tool presented in this paper has been developed to evaluate the most relevant broadband access technologies. These solutions include xDSL, HFC, PLC, FTTH, FTTC, FTTCab, and wireless alternatives such as WiMAX and satellite. The work should enable development of guidelines for broadband strategies.

BROADBAND ACCESS NETWORKS

Data transmission and networking technologies have view great growth over the past decade. But, the main part of this development and growth has been in the core networks where high capacity routers and ultra-high-capacity optical links have created a truly broadband infrastructure [4].

Globally it has been observed that several operators and vendors have chosen to deploy a hierarchic network model with three levels, taking into account geographical aspects and not necessarily functionality and capacity only [2]. A telecommunication network is commonly divided into three main parts (Figure 1): Core network; Access network; and Customer premise network.

1 João Paulo Ribeiro Pereira, Escola Superior de Tecnologia e Gestão de Bragança, Campus de Santa Apolónia - Apartado 134 - 5301-857 Bragança – Portugal, jprp@ipb.pt

2 José Adriano Pires, Escola Superior de Tecnologia e Gestão de Bragança, Campus de Santa Apolónia - Apartado 134 - 5301-857 Bragança – Portugal, adriano@ipb.pt

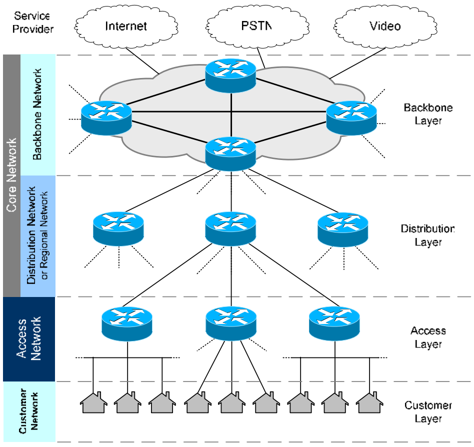


FIGURE. 1
HIERARCHICAL TELECOMMUNICATION NETWORK (THREE LEVELS).

Access Networks

Access network refers to the network between the Distribution / Regional network and the subscriber. The local access network is also often referred to as "the last mile" and "the local loop". The access network remains a bottleneck in terms of the bandwidth and service quality it affords the end user. The last mile problem has impeded the growth of broadband services and applications.

The access network is much more spread geographically and covers larger areas. The available capacity on access lines is modest with respect to availability in aggregation/distribution and core parts of the network [2]. The capacity of the access network to delivery broadband services remains as a challenge ("last mile problem").

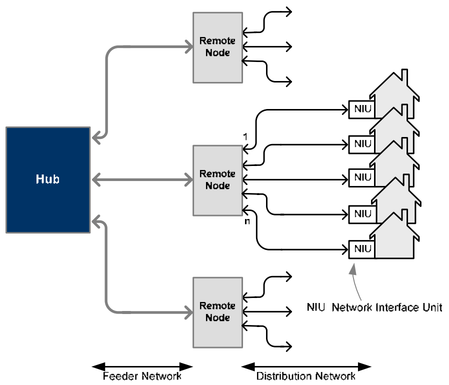


FIGURE. 2
ARCHITECTURES FOR ACCESS NETWORKS.

Then, this part of the network is usually the most expensive component in terms of capital investment and operation, administration and maintenance costs (OAM cost). Some studies reefer that this networks required 70% of the total investment.

The inadequacy of the access link (bottleneck problem) is particularly felt when the user require applications and services likely to become popular in the future. Interactive video applications, interactive gaming, video telephony, videoconferencing, remote storage, virtual DVD, and high-speed virtual private networks (VPNs) between geographically separated office locations or between homes and office locations for telecommuters are just a few such applications. It is likely that once the bandwidth and quality barrier of the access link is removed, new and unforeseen applications will emerge and attain widespread popularity. Many of these emerging applications cannot be supported with the asymmetric bandwidth available on today's access technologies. Moreover, they require guaranteed quality of service (QoS) in terms of packet delays and throughput. Thus, the capability to provide symmetric high-quality high-bandwidth bearer services will be a key requirement for access media of the future [4].

As we have refer above, there is a increasing array of access technology available. The reason for this initially was the variety of types of access infrastructure available, for example twisted pair copper, cable TV co-axial networks, the electricity distribution system, point-to-point fiber, passive optical networks (PONs), and fiber rings. More recently, alternative systems that avoid the need for infrastructure have also emerged, such as radio, satellite and free-space optics [5]. Several access technologies can be used in this part of the network: xDSL, HFC, FTTx, FWA, WiMAX, PLC, Satellite, etc. Each of these new access technologies has different performance, geographical and economic scaling attributes.

BROADBAND ACCESS TECHNOLOGIES

Broadband access technologies are being deployed to address the bandwidth bottleneck for the "last mile," the connection of homes and small businesses to this infrastructure.

As we have see above, there are a many competing technologies which can provide the bandwidth required to deliver broadband services, but each technology has its limits in terms of bandwidth, reliability, cost or coverage. At present no single technology or network architectures seems the obvious choice.

In general, broadband access technologies can be classified by the physical medium in two major groups, namely [2]:

- Wired (or fixed line) technologies: The fixed line solutions communicate via a physical network that provides a direct "wired" connection from the customer to the service supplier. Some authors divide the wired technologies in Copper-based and fiber-based.
- Wireless technologies: Wireless solutions use radio or microwave frequencies to provide a connection between the customer and the operator's network.

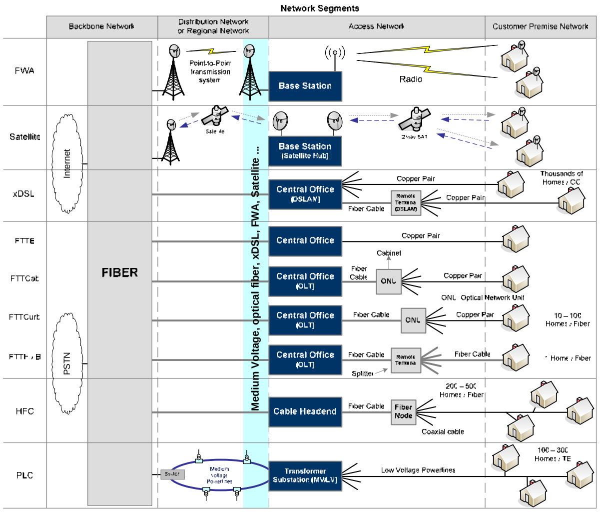


FIGURE. 4
BROADBAND ACCESS NETWORK TECHNOLOGIES.

More recently, have emerged alternative systems that avoid the need for infrastructure. Wireless broadband is the “great equalizer” of broadband technologies. It enables even those without twisted copper, coaxial cable, fiber, or satellite to enter into competition for the broadband dollar. It therefore expands the definition of who can be a carrier [6]. Covering sparsely populated areas is not economically viable using conventional techniques. The newest wireless technologies are a solution that offers wide-area coverage well suited to small villages.

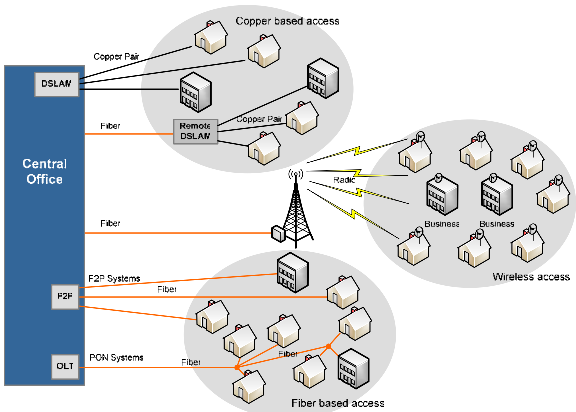


FIGURE. 4
COMBINATION OF ACCESS TECHNOLOGIES.

Today, a large variety of access network technologies and architectures are available for the operators to choose from. These include both narrowband and broadband technologies, with and without wires [7]. The selection of the best solution requires understanding of the technical possibilities and limitations of the different alternatives, as well as understanding of the costs resulting from building and operating the networks.

The choice of access technology depends on various variables like demography and geography. Others important variables are: Number of subscribers; Clients dispersion and service area; Existing infrastructures; Network architecture (Wireline, Wireless or hybrid); Services to support (like voice, data and video) and associated bit rate; Geographic characteristics; Infrastructure costs; Labor cost; Operation costs; and Access costs.

TECHNO-ECONOMIC MODEL

There are different network architectures that provide varied levels of service to the customer. Each architecture varies in complexity, network functionality, services supported and overall network costs. The network architectures and technologies will vary by cost, risk, flexibility, scalability, complexity and time to market considerations. It was argued in that the most critical parameters to include in a techno-economical model for broadband systems are subscriber density, civil works configuration, component cost evolution, and demand assessment (service penetration).

The Techno-Economic model is based on a modelling methodology for network value analysis that involves CAPEX and OPEX calculations.

Cost Model

The model analyzes several technical parameters (distances, bandwidth, equipment performance, etc.) and economic parameters (equipment costs, installation costs, service pricing, demographic distribution, etc.). Eight different technologies have been used to construct cost model. Network architectures considered include wireline technologies like xDSL, HFC, PLC, FTTH, FTTC, FTTCab, and wireless alternatives such as WiMAX and satellite.

Figure 5 show the framework architecture that supports our tool. The framework has three main components: Inputs, Processing and Outputs.

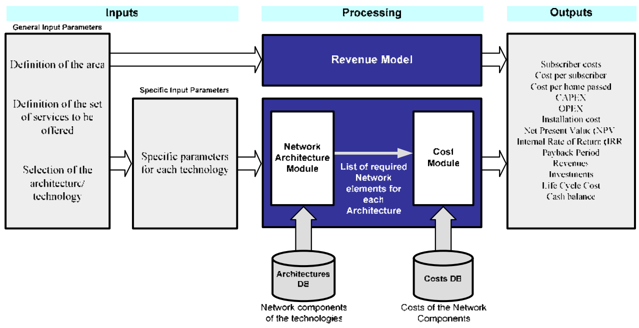


FIGURE. 5
FRAMEWORK ARCHITECTURE.

Inputs

As we have seen above, the definition of the Input attributes is fundamental to obtain the right outputs. Then, we define three main activities:

- The area definition: Selection of the geographical area; Customer segments to be served; and Existing network infrastructure situation.
- The definition of the set of services to be offered: Services to be provided; Bandwidth; Service definitions for each user segment with adoption rates and tariffs.
- The selection of the architecture/technology to be used to provide the selected services: Network architecture and technologies; Cost of network equipment and installation; Cost of operation, administration, and maintenance procedures

The model divides the inputs into two main categories: general and specific input parameters. General parameters are those that describe the area and service characteristics and are common to all the technologies (figure 6). The specific parameters are those that characterize each solution, in technological terms (see figure 7).

Processing

Architecture Module

This part of the framework is the responsible for the main outputs production. Architectures Database contains information about the components necessary to construct network architecture. This module is used to calculate the number of network elements for the set of services and the network architectures defined. The other database used in this framework is the Cost Database, containing information about the costs of the all components of each technology in study. This Database is constantly updated with data gathered from the market. The quality of the Database has a big influence in the output results. For each technology, the following attributes are necessary input to the cost module: The equipment price in a given year; Price trends; Operation, administration, and maintenance cost parameters. The technical architectures are translated into basic cost structures.

Revenues Module

This module uses some of the general input parameters to calculate the residential and business estimated revenues. The model Revenue assumptions: Type of subscribers: Residential household; and Business customer; Tariffs / fees: Yearly trend of the tariffs/fees (Connection fee (€) and Subscription fee (€ / month)).

Output Requirements

The cost module gives a range of outputs necessary for the calculation of the necessary outputs. The outputs calculated are (Figure 8): Subscriber costs; ARPU: Average Revenue Per User; Cost per subscriber; Cost per home passed; Mbit cost; OAM costs; Installation cost; Net Present Value (NPV); Internal Rate of Return (IRR); Payback Period; Revenues; Investments; Life Cycle Cost; Cash balance

TOOL DESCRIPTION

The objective of this tool is the calculation of several outputs in a given scenario, and for several BB access technologies. The tool implements a methodology for the techno-economic analysis of access networks for residential / business customers, and was being developed in MSExcel.

Figure 6 show the general input form used by the tool, where the user introduce the parameters of a given scenario:

- Area Characteristics: Geographical Area to be Covered (Km2); Number of buildings in serving area; Building density per km2 ; Average number of floors per building; Average number of living units per floor; Average number of living units per building; Total number of Living Units in area (# of potential customers); Customers units density per Km2; % Residential/Business; Total number of potential subscribers; Technology penetration rate (expected market penetration); Number of subscribers; Subscribers density per km2.
- Service Characteristics: Required Downstream bandwidth (kbps); Required Upstream bandwidth (kbps); Expected traffic demand in the area (Mbps); Expected traffic demand in the area (Mbps) per Km2; QoS for customer: % of time the Service Level Agreement is satisfied; One-time Activation/connection fee (€); Subscription fee (€ / month).

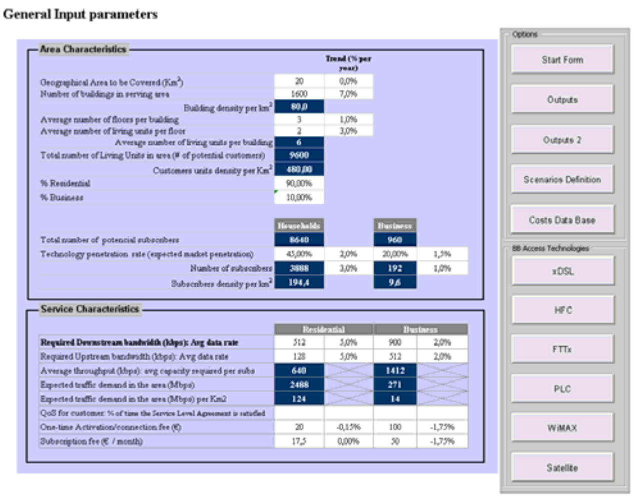


FIGURE. 6
GENERAL INPUT PARAMETERS

After the introduction of the general parameters, are required specific parameters for each technology. Figure 7 show the example of the specific parameters for the FTTx technology. The tool calculates the cost and shows the results in table, graphics and schemes (Figure 8 and 9).

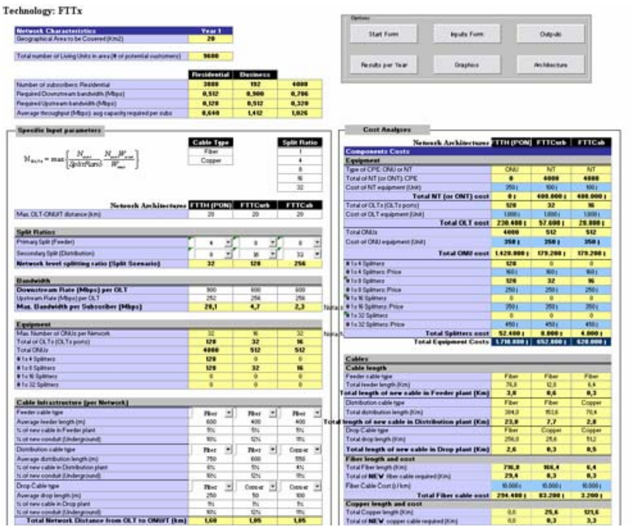
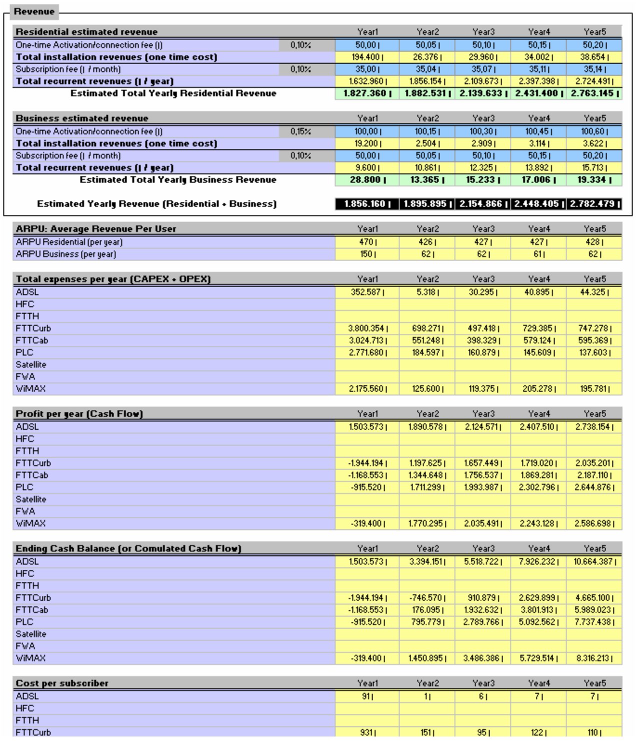


FIGURE. 7

SPECIFIC INPUT PARAMETERS (EXAMPLE OF FTTX TECHNOLOGY)

The outputs produced by the tool are presented in many formats (table, graphics and pictures). Figure 8 show some of the outputs calculated for all the solutions used in this study.



Revenue

Residential estimated revenue		Year1	Year2	Year3	Year4	Year5
One-time Activation/connection fee ()	0,10%	50,00	50,05	50,10	50,15	50,20
Total installation revenues (one time cost)		194.400	26.376	29.960	34.002	38.654
Subscription fee (/ month)	0,10%	35,00	35,04	35,07	35,11	35,14
Total recurrent revenues (/ year)		1.632.960	1.856.154	2.109.673	2.397.398	2.724.491
Estimated Total Yearly Residential Revenue		**1.827.360**	**1.882.531**	**2.139.633**	**2.431.400**	**2.763.145**

Business estimated revenue		Year1	Year2	Year3	Year4	Year5
One-time Activation/connection fee ()	0,15%	100,00	100,15	100,30	100,45	100,60
Total installation revenues (one time cost)		19.200	2.504	2.909	3.114	3.622
Subscription fee (/ month)	0,10%	50,00	50,05	50,10	50,15	50,20
Total recurrent revenues (/ year)		9.600	10.861	12.325	13.892	15.713
Estimated Total Yearly Business Revenue		**28.800**	**13.365**	**15.233**	**17.006**	**19.334**
Estimated Yearly Revenue (Residential + Business)		**1.856.160**	**1.895.895**	**2.154.866**	**2.448.405**	**2.782.479**

ARPU: Average Revenue Per User	Year1	Year2	Year3	Year4	Year5
ARPU Residential (per year)	470	426	427	427	428
ARPU Business (per year)	150	62	62	61	62

Total expenses per year (CAPEX + OPEX)	Year1	Year2	Year3	Year4	Year5
ADSL	352.587	5.318	30.295	40.895	44.325
HFC					
FTTH					
FTTCurb	3.800.354	698.271	497.418	729.385	747.278
FTTCab	3.024.713	551.248	398.329	579.124	595.369
PLC	2.771.680	184.597	160.879	145.609	137.603
Satellite					
FWA					
WiMAX	2.175.560	125.600	119.375	205.278	195.781

Profit per year (Cash Flow)	Year1	Year2	Year3	Year4	Year5
ADSL	1.503.573	1.890.578	2.124.571	2.407.510	2.738.154
HFC					
FTTH					
FTTCurb	-1.944.194	1.197.625	1.657.449	1.719.020	2.035.201
FTTCab	-1.168.553	1.344.648	1.756.537	1.869.281	2.187.110
PLC	-915.520	1.711.299	1.993.987	2.302.796	2.644.876
Satellite					
FWA					
WiMAX	-319.400	1.770.295	2.035.491	2.243.128	2.586.698

Ending Cash Balance (or Comulated Cash Flow)	Year1	Year2	Year3	Year4	Year5
ADSL	1.503.573	3.394.151	5.518.722	7.926.232	10.664.387
HFC					
FTTH					
FTTCurb	-1.944.194	-746.570	910.879	2.629.899	4.665.100
FTTCab	-1.168.553	176.095	1.932.632	3.801.913	5.989.023
PLC	-915.520	795.779	2.789.766	5.092.562	7.737.438
Satellite					
FWA					
WiMAX	-319.400	1.450.895	3.486.386	5.729.514	8.316.213

Cost per subscriber	Year1	Year2	Year3	Year4	Year5
ADSL	91	1	6	7	7
HFC					
FTTH					
FTTCurb	931	151	95	122	110

FIGURE. 8

OUTPUTS (SOME OF THE OUTPUTS PRODUCED)

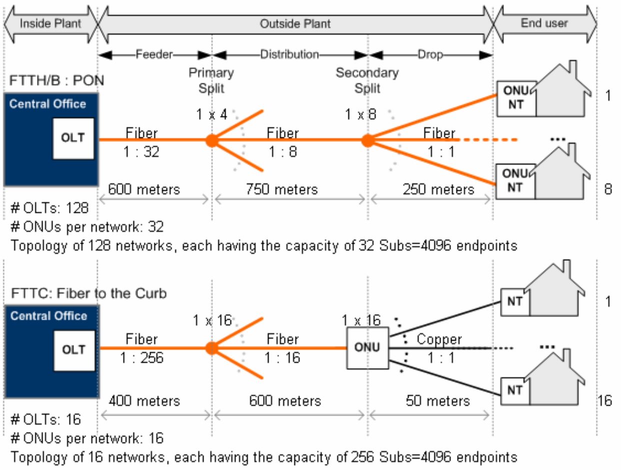


FIGURE. 9

OUTPUTS (EXAMPLE OF FTTX TECHNOLOGY)

CONCLUSION

The broadband access network remains a major challenge for operators due to the high cost sensitivity of this network segment. In this paper we present a model and a tool which can be used in the development of access networks. The tool calculates several outputs, and can be used to compare the economic viability of different network architectures in a given scenario. One of the objectives is to provide guidelines for broadband introduction in the access networks.

REFERENCES

[1] Tardy, I., L. Bråten, G. Bichot, M. Settembre, and J. Seseña, "Hybrid architecture to achieve true broadband access in rural areas", Broadband Europe, 2004, pp. 1-6.

[2] Ims, L.A., A. Bhatnagar, E. Østlyngen, and K. Bozorgebrahimi, "Towards the next generation broadband network platform," Telektronikk, pp. 107-125, Apr.2004.

[3] Ibe, O.C., "Fixed Broadband Wireless Access Networks and Services", John Wiley & Sons, Inc., 2002.

[4] Dravida. S., D. Gupta, S. Nanda, K. Rege, J. Strombosky, and M. Tandon, "Broadband access over cable for next-generation services: a distributed switch architecture," IEEE Communications Magazine, vol. 40, no. 8, pp. 116-124, Aug.2002.

[5] Cameron, A.F., D. J. Thorne, K. T. Foster, and S. I. Fisher, "Fixed access network technologies," BT Technology Journal, vol. 22, no. 2, pp. 48-59, Apr.2004.

[6] WiMAX Forum, "WiMAX Deployment Considerations for Fixed Wireless Access in the 2.5 GHz and 3.5 GHz Licensed Bands,"May2005.

[7] Smura, T., "Techno-Economic Analysis of IEEE 802.16a-Based Fixed Wireless Access Networks." Master of Science in Technology Helsinki University of Technology, 2004.